

# WEAK-FORM EFFICIENT MARKET HYPOTHESIS VERSUS BEHAVIOURAL FINANCE: A DIFFERENT PERSPECTIVE DRAWN FROM THE MALAYSIAN STOCK MARKET

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## ABSTRACT

*This study utilises the windowed testing procedure of Hinich & Patterson (1995) to examine the data generating process of KLCI returns series. Unlike previous studies, the present one relates the evidence to the weak-form Efficient Market Hypothesis (EMH) and behavioural finance, with the hope of offering some plausible explanations to the controversy existing between these two camps. Our econometrics results indicate that linear and non-linear dependencies play a significant role in the underlying data generating process. However, these dependencies are not stable as the results reveal that they are episodic and transient in nature. Along the line of our interpretations, we are able to offer some plausible explanations as to why weak-form EMH generally holds in the Malaysian stock market, though the presence of linear and non-linear dependencies implies the potential of returns predictability. Specifically, these significant dependencies show up at random intervals for a brief period of time but then disappear again before they can be exploited by investors. Looking from a micro perspective, we are able to rationalise the co-existence of weak-form EMH and behavioural finance in the Malaysian stock market when the statistical properties of random walk, linear and non-linear dependencies, which also co-exist in the time domain, are interpreted in the framework of information arrival and market reactions to that information.*

**Keywords:** Data generating process; Weak-form efficient market hypothesis; Behavioural finance; Stock market; Malaysia.

## ABSTRAK

*Kajian ini menggunakan prosedur ujian tingkap Hinich dan Patterson (1995) untuk memeriksa proses penjanaan data bagi siri pulangan KLCI. Berbeza daripada kajian-kajian lepas, kajian ini mengaitkan hasil penemuan dengan hipotesis kecekapan pasaran bentuk lemah dan kewangan kelakuan, dengan harapan memberi penjelasan yang munasabah ke atas pertikaian yang timbul antara kedua-dua pihak. Keputusan ekonometrik menunjukkan bahawa pergantungan berbentuk linear dan tak linear memainkan peranan penting dalam proses penjanaan data. Namun demikian, struktur pergantungan yang dikesan didapati tidak stabil, di mana keputusan menunjukkan gelagat pergantungan yang bersifat sekali-sekala dan juga sementara. Mengikut penafsiran, penjelasan munasabah dapat diberikan mengapa hipotesis kecekapan pasaran bentuk lemah pada amnya diterima di pasaran saham Malaysia. Sungguhpun penemuan pergantungan linear dan tak linear mengimplikasikan kebolehamalan siri pulangan tersebut. Struktur pergantungan yang dikesan itu muncul secara rawak untuk tempoh yang singkat dan seterusnya hilang sebelum dapat dieksploitkan oleh para pelabur. Melihat daripada perspektif mikro, kami mampu memberi penjelasan yang rasional tentang kewujudan bersama hipotesis kecekapan pasaran bentuk lemah dan kewangan kelakuan di pasaran saham Malaysia, apabila ciri-ciri statistik dalam bentuk pergerakan rawak, pergantungan linear dan tak linear yang juga wujud bersama dalam domain masa, ditafsirkan dalam rangka ketibaan maklumat dan reaksi pasaran terhadap maklumat tersebut.*

**Kata Kunci:** *Proses penjanaan data; Hipotesis kecekapan pasaran bentuk lemah; Kewangan kelakuan; Pasaran saham; Malaysia.*

## INTRODUCTION

The Efficient Market Hypothesis (EMH), introduced three decades ago, was a major intellectual advancement and reached its height of dominance in academic circles around the 1970s. Nowadays, it remains as one of the major building blocks of modern finance, as evidenced by its inclusion in most finance and financial economics textbooks. Briefly, Fama (1970) defined efficient market in terms of a fair game where security prices fully reflect all available information that is relevant to the determination of values. In this case, all securities are correctly priced and investors will earn a normal return on their investment that is commensurated with the level of risk assumed. One important implication is that security prices will change only when new information or news arrives that was not fully considered in forming current market prices. Even so, in an efficient market, agents



will process this new information efficiently by immediately incorporating it into the security prices. The central question that requires careful dissection here is what constitutes relevant information. This is crucial because conclusions regarding market efficiency could differ according to what is included in, or omitted from the information set. Fama (1970) has outlined a standard classification for different compositions of information set, and with this, the EMH can be classified into weak form, semi-strong form and strong form. The author explained that such classification permits researchers to pinpoint the level of information at which the hypothesis breaks down.

The weak-form EMH, which is the focus of this paper, asserts that the only relevant information set to the determination of current security prices is the historical prices of that particular security.<sup>1</sup> In this regard, investors cannot expect to find any patterns in the historical sequence of security prices that will provide insight into future price movements and allow them to earn abnormal rates of returns. In most of the empirical literature, the random walk behaviour of security prices is used as the basis to test for weak-form EMH. Since new information is deemed to come in a random fashion in an efficient market, changes in prices that occur as a consequence of that information will seem random. Thus, price movements in a weak-form efficient market occur randomly and successive price changes are independent of one another.

Formally, the random walk model can be stated as:

$$p_t = p_{t-1} + \mu_t \quad (1)$$

where  $p_t$  is the price at time  $t$ ,  $p_{t-1}$  is the price in the immediate preceding period and  $\mu_t$  is a random error term. A purely random process is what statisticians called Independent and Identical Distribution (IID), such as a Gaussian with zero mean and constant variance. The price change,  $\Delta p_t = p_t - p_{t-1}$  is simply  $\mu_t$  which being white noise, is unpredictable from previous price changes. Looking from a different perspective, Equation (1) states that the best forecast of the price of a security at time  $t+1$  is the price at time  $t$ , which in turn implies that the expected gain or loss for any holding period is zero. Therefore, analysis of past prices is meaningless because patterns observed in the past occurred purely by chance. Annuar and Shamsheer (1993), Yong (1993a) and Campbell, Lo and MacKinlay (1997), amongst others, have provided excellent reviews on the subject of random walk.

The body of literature on weak-form EMH can be considered as one of the most voluminous. Even an emerging stock market like the Kuala Lumpur Stock Exchange (now known as *Bursa Malaysia*, after the new

name was officially launched on 20 April 2004) has received considerable attention from researchers as the testing ground for weak-form EMH in those earlier years of the 1980s. Barnes (1986) examined 30 companies and 6 sector indices for the six years ended 30 June 1980. Using monthly data, the serial correlation and runs tests results exhibit a high degree of efficiency in the weak form, with little departure from the random walk hypothesis. Further spectral analysis confirms the earlier findings that the KLSE is fairly efficient. Laurence (1986) used daily closing prices adjusted for cash and stock dividends, splits and rights issues, of 16 individual stocks traded on the KLSE over the sample period of 1 June 1973 through 31 December 1978. Results from the serial correlation and runs tests suggest only slight deviation from the perfect weak-form efficiency. Using data for 6 sector indices and the all-share index from 1975 to 1982, Saw and Tan (1989) found that the Malaysian stock market is inefficient in the weak form when weekly data were used, but pockets of market efficiency existed when monthly data were used.

Entering the 1990s, weak-form EMH studies on KLSE continue to grow at a phenomenal rate, and it is impossible for us to review all of those published works in one single paper. However, our objective will have been accomplished if a comprehensive and accurate picture is presented in that not only the favourable results are reported, but also covering those evidences against weak-form EMH, if there is any. Annuar, Ariff and Shamsher (1991) conducted the weak-form test on 82 individual stocks which were continuously traded on KLSE from 1975 to 1989, using the unit root methodology to account for cyclicity in price series and controlling thin trading effect. Overall, about 87% of the total sample of 82 stocks possessed unit roots, implying that there is a 13% chance that a security price is inefficient over the fifteen-year period. Though the findings suggest the market is generally weak-form efficient, pockets of inefficiency are observed for shares that suffer liquidity problems. Annuar, Ariff and Shamsher (1993) addressed a similar issue, but using indices data in place of individual stocks, covering the sample period from January 1977 through May 1989, with weekly and monthly intervals. The results from unit root analysis, serial correlation test and *Q* statistics strongly suggest that the KLSE is weak form efficient, though, once again, pockets of inefficiency are reported for some indices. Kok and Lee (1994) analysed the stock prices behaviour of 32 companies listed on the Second Board of KLSE over the period 2 January 1992 to 30 December 1994. The results from various statistical tests—runs test, serial correlation test, Ljung-Box-Pierce *Q* test and Von Neumann's ratio test, suggest that information based on historical prices is fully reflected in current price within a week but may not be fully impounded in the current price within a day.

Thus, the Second Board of KLSE is weak-form efficient with respect to weekly data. Though daily price series are serially correlated, the magnitude of their correlations is not large enough to devise any mechanical trading rules for profitable investment timing. Kok and Goh (1995) utilised daily, weekly and monthly closing prices of seven KLSE stock indices over a period of nine years from 1984 to 1992. Using similar methodologies as Kok and Lee (1994), the authors found serial dependencies in successive price changes for all KLSE daily stock indices. However, the significant correlations found were very small that it is unlikely to have any economic value, and this led the authors to conclude the market is weak-form efficient. When weekly data were used, the efficiency of the Malaysian stock market has improved from a weak-form inefficient market in the mid 1980s to a weak-form efficient market by the late 1980s and early 1990s. Finally, the results from monthly data provide conclusive evidence of weak-form efficiency, suggesting that market efficiency improves with longer temporal aggregation of sample data. Unlike other studies, Kok and Goh (1995) proceeded to address the issue of mean reversion using long-horizon returns. Though the variance ratio test provides evidence of mean reversion, it is not statistically significant to reject the long-run random walk hypothesis.

The literature reported thus far is in favour of weak-form efficiency, though pockets of inefficiency are detected in some of those studies. However, empirical evidence of inefficiency cannot be suppressed. One of those is documented in Yong (1989) who conducted serial correlation and runs tests on weekly closing prices of 30 stocks at random over the period January 1977 to June 1988. Another significant contribution to the literature is made by Yong (1993b). To avoid being criticised of not having sample stocks that are representative of the market, Yong (1993b) used weekly closing prices of all 170 stocks traded on the KLSE from January 1977 to May 1985 inclusive. Results from various statistical tests, especially those from the runs test reinforced earlier findings of departure from weak-form market efficiency. As postulated by the author, the low trading volumes in most stocks and the possible price manipulations by those investors who own the majority of stocks might help to explain the findings of the runs test. A recent study by Lai, Balachandher and Fauzias (2003) using the variance ratio test also revealed the non-randomness of successive price changes in the KLSE. The potential of predictability is further verified by the significantly positive returns generated by the Fixed Length Moving Average (FMA) and Variable-Length Moving Average (VMA) trading rules even in the presence of trading costs, thus invalidating the weak-form EMH for the Malaysian stock market.

In a nutshell, the results from our limited survey on published studies reveal that a verdict of weak-form efficiency cannot be proclaimed for the KLSE. One notable similarity of all the above cited studies is the application of standard statistical tests- serial correlation test, runs test, variance ratio test and unit root test, to uncover linear dependencies in the data. However, the lack of linear dependencies does not imply that the series are random as there might be other more complex forms of dependencies which cannot be detected by these standard methodologies. Even Fama (1965: 80) admitted that linear modelling techniques have limitations, as they are not sophisticated enough to capture complicated patterns that the chartist sees in stock prices. Steurer (1995: 202) expressed a similar opinion, in which he argued that there is an order to the apparent randomness of the market. This order is so complex that the random walk concept is proven by the standard linear statistical tests. Another researcher, Brooks (1996: 307) agreed that the series of financial returns often appear completely random to standard linear and spectral tests. However, the author strongly believed that if a different approach is applied, using more powerful techniques, it may be possible to uncover a more complex form of dependencies in these series.

One of the possibilities that might contribute to the departure from random walk is the presence of non-linear serial dependencies in the underlying data generating process. Even the influential paper of Fama (1970: 394) acknowledged this possibility, "Moreover, zero covariances are consistent with a fair game model, but as noted earlier, there are other types of nonlinear dependence that imply the existence of profitable trading systems, and yet do not imply nonzero serial covariances". In this regard, Hinich and Patterson (1985) is the first published paper reporting evidence of non-linearity in common stock returns. As recalled by Patterson and Ashley (2000), the original manuscript of Hinich and Patterson (1985) met with resistance from the finance journals because finance academics were reluctant at that time to recognise the importance of distinguishing serial correlation from non-linear serial dependencies. Subsequent evidence documented in Scheinkman and LeBaron (1989), Hsieh (1991), Abhyankar, Copeland and Wong (1995, 1997), Barkoulas and Travlos (1998), Opong, Mulholland, Fox and Farahmand (1999), Ammermann and Patterson (2003), and Lim and Liew (2004) strongly suggested that non-linearity is a cross-sectionally universal phenomenon. This also explains the phenomenal growth of non-linear modelling in the literature as non-linearity is now widely accepted as a salient feature of financial returns in general, and stock returns series in particular.

The existence of non-linearity has strong implication on the weak-form EMH for it implies the potential of predictability in stock returns. Specifically, if investors could have profitably operated a trading rule (net of all transactions costs) that exploits this detected non-linearity, it would be at odds with the weak-form EMH, which postulate that even non-linear combinations of previous prices are not useful predictors of future prices (Brooks, 1996; Brooks & Hinich, 1999; McMillan & Speight, 2001). However, Hsieh (1989) argued that the standard statistical tests such as serial correlation test, runs test, variance ratio test and unit root tests may fail to detect non-linear departure from the random walk hypothesis. Motivated by this concern, Lim, Habibullah and Lee (2003) re-examined the random walk hypothesis as all those earlier KLSE studies in favour of weak-form EMH that have implicitly disregarded the presence of non-linearity, which will have serious consequences of making incorrect inferences and policy recommendations, as highlighted by Liew, Chong and Lim (2003). Using the Brock-Dechert-Scheinkman (BDS) test, which has been proven to be quite powerful in detecting departures from IID behaviour in some Monte Carlo simulations (see, for example, Brock, Hsieh & LeBaron, 1991; Hsieh, 1991)<sup>2</sup>, Lim, Habibullah and Lee (2003) found the inadequacy of the random walk model to describe the price behaviour of KLSE since some cycles or patterns show up more frequently than would be expected in a true random series. As those earlier studies have ruled out the possibility of linear dependencies, the departure from random walk might be due to the presence of non-linear serial dependencies. Indeed, Lim and Liew (2004) provided convincing evidence that non-linearity plays a significant role in the underlying dynamics of the Malaysian stock market.

In the weak-form test of EMH, one has to be cautious when interpreting the results of linear and non-linear serial dependencies. There is no doubt that the conclusion of weak-form market efficiency can be made when the hypothesis of random walk cannot be rejected by a robust test such as the BDS test. However, when the hypothesis is instead rejected due to the presence of certain dependency structures, it will be a strong statement to conclude that the market is inefficient. This was highlighted by Ko and Lee (1991: 224), "If the random walk hypothesis holds, the weak form of the efficient market hypothesis must hold, but not vice versa. Thus, evidence supporting the random walk model is the evidence of market efficiency. But violation of the random walk model need not be evidence of market inefficiency in the weak form". The deciding factor here is whether those detected patterns in the historical sequence of stock prices can be exploited by investors to earn abnormal rates of returns. Thus, though the evidence

of linear and non-linear dependencies implies the potential of returns predictability, it has to be further demonstrated, in order to reject the weak-form EMH, that investors are able to profitably exploit those detected underlying patterns. For instance, Kok and Lee (1994), and Kok and Goh (1995) argued that though daily price series are found to be serially correlated, the magnitude of their correlations is not large enough for any mechanical trading rules to be devised for profitable investment timing. In cases like this, the presence of linear dependencies cannot be taken as evidence against the weak-form EMH. Another excellent piece of work is provided by Ammermann and Patterson (2003), in which the detected non-linear dependency structures do not seem to be persistent enough to allow improvements over the random walk for predicting stock returns. Rather, these dependencies show up at random intervals for a brief period of time but then disappear again before they can be exploited by investors.

On the other hand, relating the existence of linear/non-linear dependency structures to the concept of information arrival and market reactions to that information will prove to be enlightening. A similar attempt by Ramsey and Zhang (1997) to tie their results of *localized frequency bursts* to news events is able to provide useful insights into market behaviour. In this regard, the EMH asserts that if the market is efficient, then new information will be reflected quickly and unbiasedly into market prices.<sup>3</sup> Conversely, in an inefficient market, there will either be an over-reaction or a delayed response, where it takes some time before reaching the equilibrium price. Statistical findings of random walk movements in historical price series provide evidence of weak-form market efficiency, indicating that new information is quickly impounded in current market prices. In contrast, evidence of linear/non-linear dependency structures reflect those periods in which the speed of adjustment to new information is not immediate, due to certain underlying factors. For instance, Ammermann and Patterson (2003) found that the detected linear serial dependencies in their studies are driven, at least in part, by the price limits that were imposed on the market, which caused the instances of significant autocorrelation to be heavily clustered. This is not surprising as Ryoo and Smith (2002) also found that effective price limits prevent market prices from following a random walk and as a result, induce auto correlation. The explanation for the existence of linear dependencies driven by price limits can be found in Fama (1970), in which the author postulated that price limits will delay the adjustment of prices to the new equilibrium value and hence result in the market being inefficient. On the other hand, Brooks, Hinich and Molyneux (2000) attributed the

findings of non-linear dependencies to two important events that occurred during their sample period-widespread upsets in the currency markets and a change in U.S. accounting procedures that affected U.S. firms with business abroad. The authors explained that when surprises hit the market, they generally generate a pattern of non-linear price movements relative to previous movements since the traders are unsure of how to react and hence they respond slowly. Another recent work by Lim, Azali and Habibullah (2003) found evidence of non-linearity in the underlying data generating process of bilateral Malaysian ringgit-U.S. dollar which can be attributed to central bank interventions that stopped the exchange rates from moving freely and reacting completely and immediately to new information.

This study attempts to provide deeper insights into the stock price behaviour in KLSE, with the hope of throwing some light on the existing controversy between the two camps of weak-form EMH and behavioural finance. Briefly, behavioural finance is built on two major building blocks, that is cognitive psychology (how people think) and limits to arbitrage (when markets will be inefficient), to explain the irrational financial behaviour of investors, either due to preferences or mistaken beliefs (see, for example, De Bondt & Thaler, 1985; Shefrin, 2000; Shiller, 2000; Hirshleifer, 2001; Barberis & Thaler, 2003; Ritter, 2003). In fact, investors in general will not behave rationally all the time in their decisions as postulated by EMH; there will be periods of irrationality reflected by over- or under-reaction. As explained by Schachter, Gerin, Hood and Andreassen (1985: 324), "The investor is something more than the creature the economist hypothesizes. As well as the rational, utility maximizer of the economist's creation, the investor is also a social creature influenced by the opinions and actions of others as well as by his own assessment of hard, economic facts". Empirically, Schachter *et al.* (1985) found that the South Sea Bubble during 1720 was a time of hysteria when all common sense, let alone rationality, abandoned the aggregate of investors. On the home front, Annuar (2002) provided an excellent survey on market inefficiencies of the KLSE in the context of behavioural finance. Another recent study by Lim, Habibullah and Lee (2004) found evidence supporting their conjecture that the 1997 Asian financial crisis contributed to the non-random behaviour of stock prices as those panic-stricken investors are not able to make a rational assessment of the market and adjust rapidly and unbiasedly to the arrival of new information. These empirical evidences of irrational behaviour, just to highlight a few, compel researchers to seek alternative explanations and hence contribute to the growth of behavioural finance, posing a direct challenge to EMH.

However, this study does not side with either camp in this controversy. Instead, we attempt to shed some interesting light by statistically demonstrating that both the weak-form EMH and behavioural finance can co-exist in the time domain. In this regard, due credit should be given to Annuar (2002), which has been the source of our inspiration. In a culmination of more than ten years of research on the KLSE, Annuar (2002: 15) wisely penned his concluding remarks, "I conclude that, given the world and KLSE evidence both collaboratory and contradictory, market efficiency and behavioural finance co-exist just as God created us and many observations in pairs. Chaotic (irrational) and rational behaviours co-exist in any market be it efficient, moderately efficient and inefficient. At times, we may act rationally; at other times irrationally. It is a matter of degree." Using data from the KLSE and windowed testing procedure proposed by Hinich and Patterson (1995), we are able to rationalise the co-existence of weak-form EMH and behavioural finance, and hence provide empirical content to the above statement. Browsing those earlier KLSE studies, we found traces of evidence that support this conjecture, such as the findings of pockets of efficiency/inefficiency documented in Saw and Tan (1989) and Annuar *et al.* (1991, 1993). The sub-period analysis conducted by Kok and Goh (1995) is motivated by the possibility that a significant result for the whole period could be attributed to any particular sub-period, suggesting that the authors were aware the weak-form EMH might not hold all the time.

This study is further motivated by the empirical findings of episodic transient dependencies detected in most financial time series. Brooks and Hinich (1998) found that the Sterling exchange rates are characterised by transient epochs of dependencies surrounded by long periods of white noise. In Ammermann and Patterson (2003), a closer examination via the windowed-testing procedure of Hinich and Patterson (1995) reveal that the detected non-linear dependencies do not appear to be cross-temporally universal in that there are a few brief periods in which the dependencies are very noticeable while other periods, in fact most of the time, the returns rather closely approximate a random walk. This means that the significant full sample results for non-linearity are actually triggered by the activity within a few relatively short *pockets* of highly non-linear data. Unlike the above two studies, Ramsey and Zhang (1997) utilised the waveform dictionaries approach and found similar structures which they described as localised frequency bursts, representing intense activity that is local in time and in frequency. Ramsey and Zhang (1997: 364) interpreted their results in such a way, that "the potential implications for understanding



behaviour are that even over a low frequency range, price activity can be characterized by intermittent bursts of activity involving a relatively narrow range of frequencies, separated by relative quiescent periods." This new-found feature has direct bearing on the weak-form EMH and behavioural finance when the statistical properties of random walk, linear and non-linear dependencies are interpreted in the framework of information arrival and market reactions to that information. Specifically, the evidence of episodic transient dependencies suggests that there are periods when investors react rapidly to the arrival of new information (reflected in the random walk price movements and hence taken as evidence of EMH), while at other times information is incorporated slowly into market prices (reflected in those clusters of linear/non-linear dependencies and is generally taken as evidence of behavioural finance). In order to justify the co-existence of weak-form EMH and behavioural finance in the time domain, the crucial task is to determine whether the price series in KLSE are also characterised by such episodic transient behaviour of dependencies.

As mentioned earlier, the tool which is capable of performing this task is the windowed testing procedure by Hinich and Patterson (1995). The test is designed to detect episodes of transient serial dependencies within a data series, by breaking the full sample into smaller subsamples or windows of data. In other words, this procedure examines whether the dependencies found in the full sample are in fact due to strong but episodic occurrences that appear only infrequently and fleetingly. Hinich and Patterson (1995), Brooks and Hinich (1998), Brooks *et al.* (2000), Patterson and Ashley (2000) and Ammermann and Patterson (2003) have utilised this procedure to investigate the time series properties and stability of the underlying dynamics of financial data. Unlike all these earlier studies in which the contribution is methodological, the present study adopts the Hinich and Patterson (1995) methodology but relates the evidence to the popular weak-form EMH and behavioural finance, with the hope of offering some plausible explanations to the controversy between these two camps.

Following this, a brief description of the data and the methodology used in the present study is given. The subsequent sections present the empirical results as well as their interpretations in the framework of market behaviour. Finally, concluding remarks and some recommendations for further research are provided at the end of the paper.

## METHODOLOGY

### The Data

In this study, we utilised the daily closing values of the Kuala Lumpur Composite Index (KLCI) for the sample period from 2 January 1990 to 31 December 2002. The price series obtained are used to compute a set of continuously compounded percentage returns for the KLCI, using the relationship:

$$r_t = 100 * \ln(p_t / p_{t-1}) \quad (2)$$

where  $p_t$  is the closing price of the stock on day  $t$ , and  $p_{t-1}$  the price on the previous trading day.

### Hinich and Patterson (1995) Windowed Testing Procedure

In the windowed testing procedure by Hinich and Patterson (1995), a correlation portmanteau test similar to the Box-Pierce  $Q$ -statistic is developed for the detection of correlation or linear serial dependencies within a window. For detecting non-linear serial dependencies within a window, the procedure uses a bicornelation portmanteau test, which can be considered as a time-domain analog of the Hinich bispectrum test statistic (Hinich, 1982). In applying these tests, the full sample is broken down into smaller sub-samples or windows of data. If the full data sample does exhibit significant linear or non-linear serial dependencies, but there are only a few smaller windows that are significant, then this suggests the data may instead be characterised by episodes of transient dependencies. In other words, it is the activity of these few windows that is actually driving the results of the overall sample. As demonstrated in the Monte Carlo simulations of Hinich and Patterson (1995), the test performs well even with small sample sizes.

In this section, we provide a brief description of the windowed testing procedure and the test statistics employed.<sup>4</sup> Let the sequence  $\{y(t)\}$  denote the sampled data process, where the time unit,  $t$ , is an integer. The test procedure employs non-overlapped data window, thus if  $n$  is the window length, then  $k$ -th window is  $\{y(t_k), y(t_k+1), \dots, y(t_k+n-1)\}$ . The next non-overlapped window is  $\{y(t_{k+1}), y(t_{k+1}+1), \dots, y(t_{k+1}+n-1)\}$ , where  $t_{k+1} = t_k + n$ . The null hypothesis for each window is that  $y\{t\}$  are realisations of a stationary pure noise process<sup>5</sup> that has zero bicovariance. The alternative hypothesis is that the process in the window is random with some non-zero correlations  $C_{yy}(r) = E[y(t)y(t+r)]$

or non-zero bicornrelations  $C_{yyy}(r, s) = E[y(t)y(t+r)y(t+s)]$  in the set  $0 < r < s < L$ , where  $L$  is the number of lags.

Define  $Z(t)$  as the standardised observations obtained as follows:

$$Z(t) = \frac{y(t) - m_y}{s_y} \quad (3)$$

for each  $t = 1, 2, \dots, n$ , where  $m_y$  and  $s_y$  are the sample mean and sample standard deviation of the window.

The sample correlation is:

$$C_{zz}(r) = (n-r)^{-1/2} \sum_{t=1}^{n-r} Z(t)Z(t+r) \quad (4)$$

The  $C$  statistic, which is developed for the detection of linear serial dependencies within a window, is defined as:

$$C = \sum_{r=1}^L [C_{zz}(r)]^2 \sim \chi^2_{(L)} \quad (5)$$

The  $(r, s)$  sample bicornrelation is:

$$C_{zzz}(r, s) = (n-s)^{-1} \sum_{t=1}^{n-s} Z(t)Z(t+r)Z(t+s) \quad \text{for } 0 \leq r \leq s \quad (6)$$

The  $H$  statistic, which is developed for the detection of non-linear serial dependencies within a window, is defined as:

$$H = \sum_{s=2}^L \sum_{r=1}^{s-1} G^2(r, s) \sim \chi^2_{(L-1)(L/2)} \quad (7)$$

where  $G(r, s) = (n-s)^{1/2} C_{zzz}(r, s)$

In both the  $C$  and  $H$  statistics, the number of lags  $L$  is specified as  $L = n^b$  with  $0 < b < 0.5$ , where  $b$  is a parameter under the choice of the user. Based on the results of Monte Carlo simulations, Hinich and Patterson (1995) recommended the use of  $b = 0.4$  in order to maximise the power of the test while ensuring a valid approximation to the asymptotic theory.

A window is significant if either the  $C$  or  $H$  statistic rejects the null of pure noise at the specified threshold level. This study uses a threshold of 0.01. In this case, the chance of obtaining a false rejection of the null is approximately one out of every 100 windows. With such a low-level threshold, it would minimise the chance of obtaining false rejections

of the null hypothesis indicating the presence of dependencies where these actually do not exist.

Another element that must be decided upon is the choice of the window length. In fact, there is no unique value for the window length. According to Brooks and Hinich (1998), the window length should be sufficiently long to provide adequate statistical power and yet short enough for the test to be able to pinpoint the arrival and disappearance of the transient dependencies, which is the main purpose of using the windowed testing procedure. In this study, we follow the choice of Brooks and Hinich (1998) in which the data are split into a set of non-overlapping windows of 35 observations in length, approximately seven trading weeks. In fact, it was found that the choice of the window length does not alter much of the results of both test statistics.

EMPIRICAL RESULTS

Table 1 provides summary statistics for the KLCI returns series in order to get a better view of some of the important statistical features. The mean of the returns series is quite small. For the third central moment, the result indicates some degree of positive or right-skewness. The fourth central moment, on the other hand, reveals that the distribution of the series is highly leptokurtic, in which the tails of its distribution taper down to zero more gradually than do the tails of a normal distribution. Not surprisingly, given the non-zero skewness level and excess kurtosis demonstrated within these series of returns, the Jarque-Bera (JB) test strongly rejects the null of normality.

Table 1  
Summary Statistics for KLCI Returns Series

	KLCI Returns Series
Sample Period	2/1/1990-31/12/2002
Number of observations	3391
Mean	0.004108
Median	0.000000
Maximum	20.81737
Minimum	-24.15339
Standard deviation	1.654112
Skewness	0.467365
Kurtosis	38.86546
JB normality test statistic	181871.3
p-value	(0.000000)*

\* denotes extremely small p-value.

Table 2 presents the correlation ( $C$ ) and bicornelation ( $H$ ) test statistics for the KLCI returns series covering the full sample period. The results reveal that both the  $C$  and  $H$  statistics are highly significant, with extremely small  $p$ -values.<sup>6</sup> This indicates the presence of strong non-linear serial dependencies, in addition to autocorrelation, in the underlying generating process of the KLCI returns series. The findings of non-linearity corroborate those of Lim and Liew (2004) in which the authors utilised the Lukkonen-Saikkonen-Teräsvirta linearity test (Luukkonen, Saikkonen & Teräsvirta, 1988) and Hinich bispectrum test.

**Table 2**  
 **$C$  and  $H$  Statistics for KLCI Returns Series**

KLCI Returns Series	
Sample Period	2/1/1990-31/12/2002
Number of observations	3391
Number of lags	26
Number of bicornelations	325
$p$ -values	
- $C$ Statistic	0.0000*
- $H$ Statistic	0.0000*

\* denotes extremely small  $p$ -value.

Subsequently, we examined whether the detected dependency structures in the full sample, both linear and non-linear, were in fact due to strong but episodic occurrences that appear only infrequently and fleetingly. Table 3 shows the results for the windowed testing, in which the data are split into a set of non-overlapping windows of 35 observations in length, approximately seven trading weeks each. In this case, four lags are used in calculating both the  $C$  and  $H$  statistics. The fifth row in Table 3 shows the number of windows where the null of pure noise is rejected by the  $C$  statistic.<sup>7</sup> In parenthesis is the percentage of significant  $C$  windows. The results show that the null is rejected in six windows by the  $C$  statistic, which is equivalent to 6.25%. By using a threshold level of 0.01, we would expect the  $C$  statistic to reject 1% of the windows by random chance. However, the percentage of windows exhibiting significant linear serial dependencies is greater than the expected 1%. Similarly, the percentage of significant  $H$  windows is also larger than the 1% nominal threshold level, as displayed in the seventh row of the same table.

Since both the  $C$  and  $H$  statistics are highly significant for the full data series as reported in Table 2, one would expect these serial dependencies to be persistent throughout the data or at least many more of the

windows to exhibit strong serial dependencies. Instead, these significant test results in the full data series are reflected in only a relatively few windows. In other words, it is the activity of these few windows that is actually driving the results of the overall sample. Specifically, out of the total 96 windows, only six (6.25%) exhibit significant linear serial dependencies and four (4.17%) exhibit non-linear serial dependencies. Taken together, there are a total of 10 windows (10.42%) where the null of pure noise is rejected, as shown in the final row of Table 3. These episodic transient features detected in the data indicate that the KLCI returns series are not stable, with the returns during most of the time periods move along at a close approximation to random walk, while during the remaining ten sub-periods they are characterised by highly significant linear and non-linear serial dependencies. The windowed testing procedure has an added advantage in that it permits a closer examination of the precise time periods during which the linear and non-linear dependencies are occurring. Table 3 also reports these time periods, which are potentially useful for our future investigation into the causes of these detected episodic transient dependencies, as performed by Brooks *et al.* (2000) and Ammermann and Patterson (2003).

**Table 3**  
 Windowed Testing Results for KLCI Returns Series

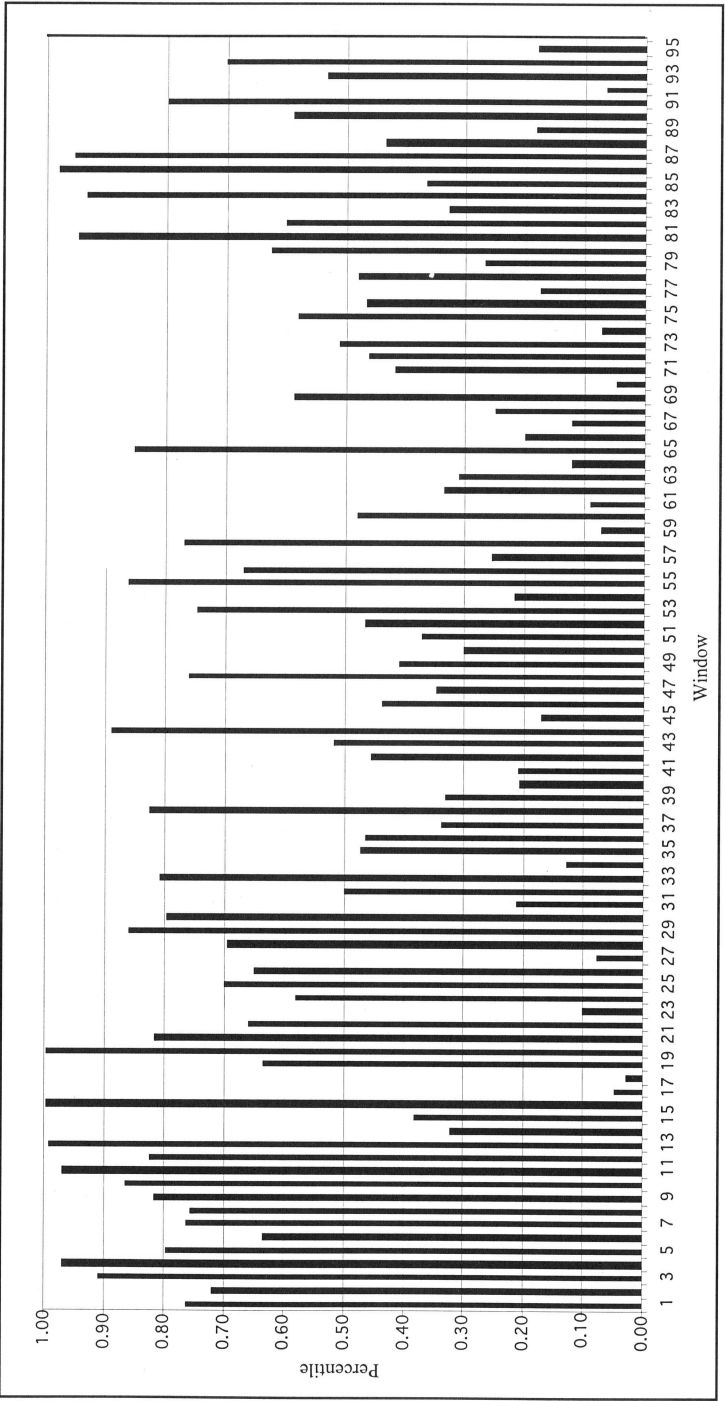
	KLCI Returns Series
Total number of windows	96
Number of lags	4
Number of b correlations	6
Significant C windows	6 (6.25%)
Dates of significant C windows	29/5/1990-16/7/1990 7/5/1991-24/6/1991 13/8/1991-30/9/1991 7/1/1992-24/2/1992 21/7/1992-7/9/1992 29/5/2001-16/7/2001
Significant H windows	4 (4.17%)
Dates of significant H windows	17/7/1990-3/9/1990 5/3/1996-22/4/1996 4/8/1998-21/9/1998 4/9/2001-22/10/2001
Significant C and H windows	10 (10.42%)

This episodic and transient behaviour of dependencies can be observed graphically. The histograms in Figure 1 and Figure 2 show the percentiles (i.e. one minus the  $p$ -value) into which the  $C$  and  $H$  statistics fall in each window for the KLCI returns series. Thus, a very significant window is plotted as a value near 1.0. It can be observed from these figures the episodic occurrence of the dependencies that appear within the data infrequently. Another interesting feature is the transient nature of these dependencies, in which some windows appear highly significant, but then quickly disappear, or become too weak to be detected, in subsequent windows. Figure 3 shows those significant  $C$  and  $H$  windows, which is only 10 in total, suggesting that they are not stable and persistent. It is clear from this final figure that the returns move closely approximating a random walk during most of the time.

## INTERPRETATIONS

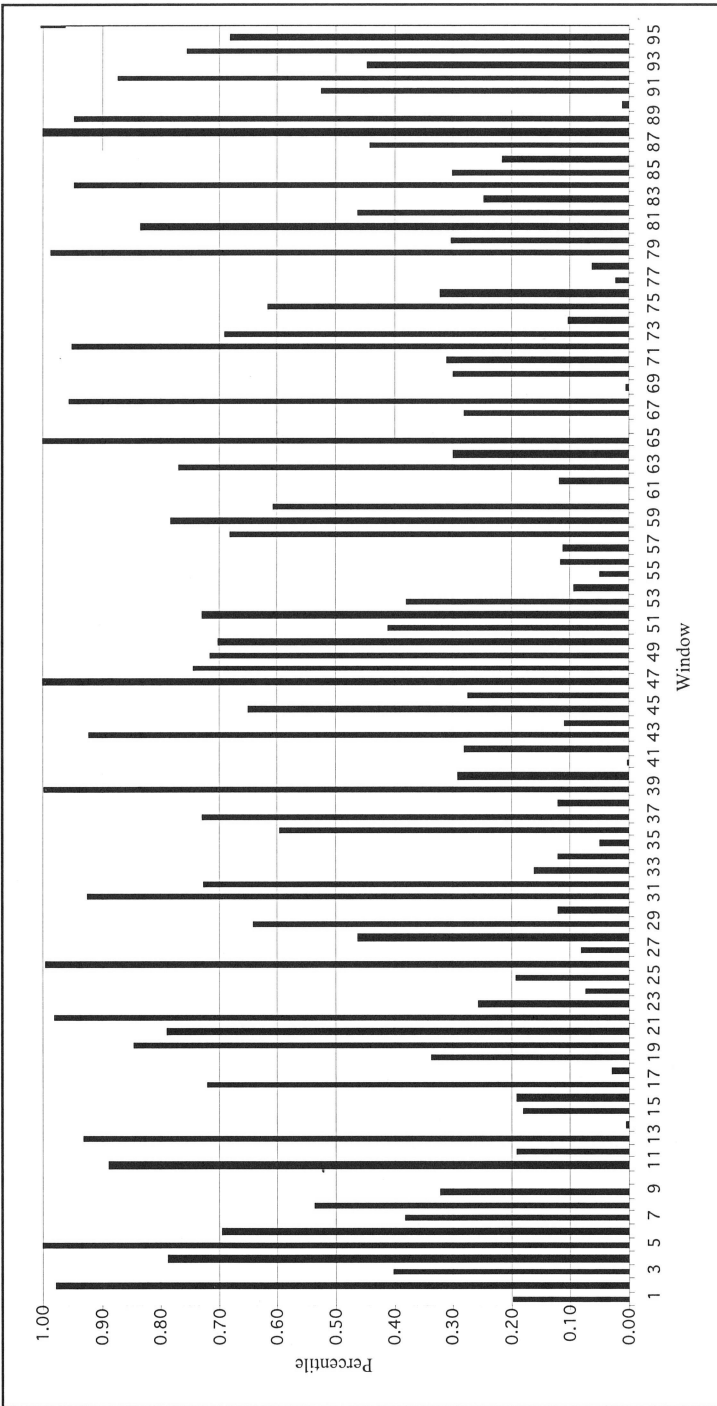
Given that the KLCI returns series are characterised by episodic transient behaviour of dependencies, how does this evidence relate to the weak-form EMH and behavioural finance? This section sheds some light on the controversy and justifies the co-existence of weak-form EMH and behavioural finance.

Looking at the results as a whole, the evidence of linear and non-linear dependencies indicates departure from random walk and hence implies the potential of returns predictability. However, as discussed in the earlier section, in order to reject the weak-form EMH, one has to demonstrate that investors are able to profitably exploit these detected dependency structures. The episodic transient feature of these dependencies suggests that they are not stable and persistent enough for investors to benefit from it. As depicted in Figure 3, these significant dependencies show up at random intervals for a brief period of time but then disappear again before they can be exploited. Thus, it is not surprising to learn that though non-linearity is a salient feature of financial time series, researchers have thus far failed to exploit the detected non-linearity in making improved point forecasts. This issue was well posed by Diebold and Nason (1990: 317), who wrote: "Why is it that while statistically significant rejections of linearity in exchange rates and many other economic and financial series routinely occur, no nonlinear model has been found that can significantly outperform even the simplest linear model in out-of-sample forecasting?" The results, taken as a whole, do not constitute evidence against the weak-form EMH.



**Figure 1**  
C statistics for KLCI returns series





**Figure 2**  
*H* statistics for KLIC returns series

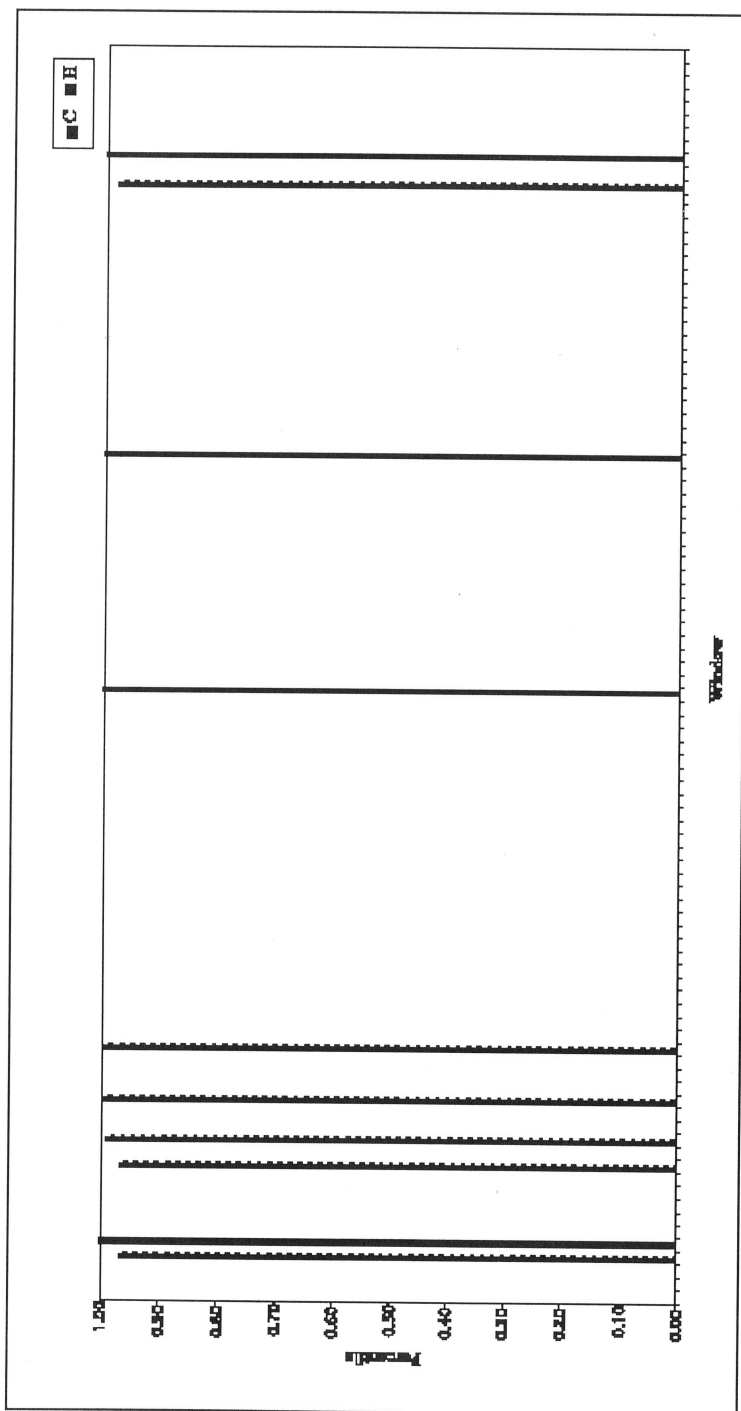


Figure 3  
Significant  $C$  and  $H$  statistics for KLIC returns series

When these empirical findings are put under the microscope, we are able to rationalise the co-existence of weak-form EMH and behavioural finance. The results, which are best illustrated by Figure 3, suggest that there are a few brief periods in which the dependencies, linear and non-linear, are very noticeable while other periods, in fact most of the time, show returns as closely approximating a random walk. When these statistical properties of random walk, linear and non-linear dependencies are interpreted in the framework of information arrival and market reactions to that information, then it becomes clear that the weak-form EMH and behavioural finance do in fact co-exist, at least in the context of the Malaysian stock market. Specifically, the long periods of pure noise reflect the movements of financial returns that closely approximate a random walk. In this regard, the market adjusts rapidly to the arrival of new information and this can be taken as evidence supporting the EMH. In contrast, those brief periods of linear/non-linear dependencies suggest that information is incorporated slowly into market prices or it takes some time for market prices to reach the equilibrium value, either due to over- or under-reaction of behavioural finance. Thus, following this line of interpretation, the episodic transient feature of KLCI returns series empirically support the co-existence of weak-form EMH and behavioural finance, as postulated by Annuar (2002). To be more precise, during most of the time periods, the market is weak-form efficient. There are only a few brief periods in which investors are not able to make a rational assessment of the market and adjust rapidly and unbiasedly to the arrival of new information. This is not surprising as we browse through those earlier KLSE studies, most of the empirical results support weak-form EMH, with only a few exceptions. However, we recognise that these interpretations, though supported to some extent by our econometrics findings, remain conjectures. We invite alternative explanations of our econometric findings.

## CONCLUSIONS AND RECOMMENDATIONS

This study utilised the windowed testing procedure by Hinich and Patterson (1995) to examine the data generating process of KLCI returns series. Unlike previous studies, the present one relates the evidence to both the popular weak-form EMH and behavioural finance, with the hope of offering some plausible explanations to the controversy between these two camps. Our econometrics results indicated that linear and non-linear dependencies play a significant role in the underlying data generating process. However, these dependencies are not stable, since the results revealed that they are episodic and transient

in nature. Along the line of our interpretations, we were able to offer some plausible explanations as to why weak-form EMH generally holds in KLSE, though the presence of linear and non-linear dependencies implies the potential of returns predictability. Specifically, these significant dependencies show up at random intervals for a brief period of time but then disappear again before they can be exploited by investors. Looking from a micro perspective, we are able to rationalise the co-existence of weak-form EMH and behavioural finance in KLSE when the statistical properties of random walk, linear and non-linear dependencies, which also co-exist in the time domain, are interpreted in the framework of information arrival and market reactions to that information.

Though this study does not address the issue of model adequacy, the characteristics found in these returns series can be used to construct a better econometric model. However, given the complexity of the generating mechanism, it would certainly pose a challenge to researchers in constructing a model that could adequately capture these important features of the data. For example, it was highlighted by Brooks and Hinich (1998) that these transient epochs of dependencies could not be generated by any kind of ARCH or GARCH model. Even with some modifications, such as those by Booth, Martikainen, Sarkar, Virtanen and Yli-Olli (1994) which augment the GARCH equation with structural breaks in the mean or those by Hamilton and Susmel (1994) which allow the parameters of the GARCH equation to be drawn from one of several regimes, they still could not capture these dependencies. Another related study by Ramsey and Zhang (1997) using waveform dictionaries also found similar structures which the authors describe as “localized frequency bursts”. These authors suggested that the relevant model is one of oscillations induced by packets of information that leave the median of changes invariant to zero. The packets are characterised in time frequency space by short bursts of activity over narrow frequency ranges. This would certainly be a stimulating task.

It would also be interesting to investigate the events that trigger these irrational reactions of investors in KLSE during those brief periods. This is possible because the windowed testing procedure by Hinich and Patterson (1995) permits a closer examination of the precise time periods during which those dependencies, linear and non-linear, are occurring, as reported in Table 3. For instance, in the work of Ammermann and Patterson (2003), the linear dependencies are found to be directly attributable to changes in the Taiwan Stock Exchange's price limits that were made during 1987 and 1988. Brooks *et al.* (2000) found that the non-linear dependency structures in their data were

due to widespread upsets in the currency markets and a change in US accounting procedures. This line of inquiry is certainly worth investigating and will be included in future research agenda.

## END NOTES

- <sup>1</sup> Fama (1970) also defined the other two versions of EMH. The semi-strong form assumes that prices fully reflect all obvious publicly available information, while the strong form is concerned with whether individual investors or groups have monopolistic access to any information relevant to price formation.
- <sup>2</sup> Specifically, the BDS test has good power to detect at least four types of non-IID behaviour: non-stationarity, linear dependencies, non-linear stochastic process, and non-linear deterministic process.
- <sup>3</sup> Three important dimensional aspects can be abstracted from price reaction to new information, namely magnitude, direction and speed (for details, refer Annuar, 2002). Our interpretation is concerned with the speed of price adjustment to new information, which has received less attention in the literature as compared to the other two dimensions of market efficiency.
- <sup>4</sup> Interested readers can refer to Hinich and Patterson (1995) and Hinich (1996) for a full theoretical derivation of the test statistics and some Monte Carlo evidence regarding the size and power of the test statistics.
- <sup>5</sup> A stationary time series is called pure-noise or pure white-noise if  $y(n_1), \dots, n_N$ . A white noise time series, by contrast is one for which the autocovariance function is zero for all lags. Whiteness does not imply that  $y(n)$  and  $y(m)$  are independent for  $m \neq n$  unless the series is Gaussian.
- <sup>6</sup> Instead of reporting the  $C$  and  $H$  statistics as chi-square variates, the T23 program written by Melvin J. Hinich reports the statistics as  $p$ -values. Based on the appropriate chi square cumulative distribution value, the T23 program transforms the computed statistic to a  $p$ -value.
- <sup>7</sup> In this study, the threshold level has been set at 0.01. The level of significance is the bootstrapped thresholds that correspond to 0.01.

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